MANAGEMENT OF DIABETIC KETOACIDOSIS

Establish the diagnosis of DKA

1. Clinically
   - Suspected in any infant or child with dehydration or signs of hypovolemia (tachycardia and poor peripheral perfusion) with deep sighing (Kussmaul) respiration.
   - Associated symptoms
     a) Nausea, vomiting
     b) Abdominal pain
     c) Confusion, drowsiness or loss of consciousness
     d) History of polyuria, polydipsia, weight loss, tiredness (1-3 weeks ago)
2. Laboratory
   - Random blood glucose > 200 mg/dl by glucometer while awaiting the result of serum blood glucose for confirmation
   - Venous pH <7.3 or bicarbonate <15 mmol/L (metabolic acidosis)
   - Urine: ketonuria (using urine ketone strips) or ketonemia ≥ 3 mmol/L

Immediate clinical assessment for

1. Airway
2. Vital signs: pulse, respiratory rate, blood pressure and body temperature (attach monitor and pulse oximeter)
3. Level of consciousness level (use Glasgow coma scale) and pupillary reaction
4. Degree of dehydration
   - 5% dehydration: capillary refill > 2 seconds -poor skin turgor - tachypnea
   - 10% dehydration : weak pulse – oliguria – mottled cold extremities - blood pressure below the 5th percentile (2nd degree shock)
5. Weight of the patient
6. Urine collection in a sterile bag without unnecessary catheterization

Order the following laboratory tests

1. **Blood gases** (venous sample- no need for arterial) to define the severity of DKA

Mild: pH<7.3 or bicarbonate <15 mmol/L
Moderate: pH<7.2 or bicarbonate <10 mmol/L
Severe: pH<7.1 or bicarbonate <5 mmol/L

2. Serum Electrolytes: **Na, K and Chloride.** If laboratory measurement of serum potassium is delayed, perform an electrocardiogram (ECG) for baseline evaluation of potassium status.
3. Calculate the **anion gap**: $(Na^+) - (HCO3^- + Cl^-)$
   - Normal anion gap equals 12± 2 mmol/L. In DKA, the anion gap is typically 20–30 mmol/L; anion gap >35 mmol/L suggests concomitant lactic acidosis
4. Calculate **corrected Na^+**: Measured Na^+ + 2 [(glucose mg/dl – 100)/100]
5. **Serum Osmolality** (mosm/kg).
   - Effective osmolality = 2 (Na^+) + glucose [mg/dl]/18
6. Urine for **ketones**
7. **Blood urea nitrogen** and serum **creatinine**
8. Complete blood count (CRP and clinical assessment of the possibility of infection is essential as leukocytosis occurs with the stress of DKA in absence of infection)
9. **BUN, Hb, Ht, and serum proteins are important to determine the degree of dehydration.**
10. Urine analysis: to exclude U.T.I.
11. If available
    - Serum BOHB
    - Serum lactate (indicate shock or sepsis)
    - HbA1c

Management

1. Airway: Secure airway. Use free flow of oxygen if patient is in shock. If there is history of recent fluid intake evacuate the stomach by nasogastric tube to avoid aspiration, also to control hyperglycemia if the patient has consumed a lot of carbohydrate containing fluids (juices), as with the treatment of DKA gastroperesis resolves and results in exacerbation of hyperglycemia due to gastric emptying.

2. Peripheral line insertion, NOT central (central line carries more risk for thrombosis and embolism and if used as a common inlet for fluids and insulin, insulin flow may be interrupted).
3. Cardiac monitoring (ECG).
4. Catheterization of the bladder only in unconscious or extremely ill infants.
5. Give antibiotics to febrile patients after obtaining appropriate cultures of body fluids.

Goals of Therapy

1. Correct dehydration
2. Correct acidosis
3. Reverse ketosis
4. Slowly correct hyperosmolality
5. Restore BG to near normal
6. Monitor for complications of DKA and its treatment
7. Identify and treat any precipitating event

I. Fluids Therapy

Initial Fluids Therapy

If the patient is shocked give bolus of 10 -20 ml /kg Isotonic saline 0.9% rapidly and reassess (could be repeated **but not exceeding 30 ml/kg)**

If the patient is severely dehydrated (not shocked) give bolus of 10 – 20 ml/kg over 1-2 hours (could be repeated **but don't exceed 30 ml/kg)**

If the patient shows mild to moderate dehydration start the deficit+maintenance therapy without bolus fluids

Further Fluids Therapy

Total working fluids = (deficit +maintenance for 48 hr) - boluses given

Deficit

Deficit (litres) = % dehydration x body weight (kg)

- Ensure this result is then converted to ml.
- Assess degree of dehydration as previously mentioned

Maintenance

- Use the Holliday-Segar formula
  ≤10 kg → 100 mL/kg/24h
  11–20 kg → 1000 mL + 50 mL/kg/24 h for each kg from 11–20
  >20 kg → 1500 mL + 20 mL/kg/24 h for each kg >20
- OR according to body surface area for children more than 10 kg → 1500 ml/m^2/day
- Calculate the maintenance for 48 hrs

Fluids rate

- The total working fluids should be given **evenly** over 48 hours.
- In severe hyperosmolarity (>340) or corrected Na >155, fluids are given over 72 hours to avoid brain edema.
- The rate of fluid administration should not exceed 1.5–2 times the usual daily maintenance requirement.

Type of fluids

1. **The first 4-6 hours:** always use normal saline (0.9% saline) to restore good perfusion.
2. **The next 42-44 hours:** use a concentration of half normal saline or above (> 0.45% saline) as a sum of deficit and maintenance calculated according to the body weight.
   The saline concentration should be adjusted to achieve a positive sodium trend (steady rise of measured serum Na). Observe for Na trend every 2- 4 hours.
   - Positive Na trend (i.e. increase of corrected Na by 2.77 mEq/l with every 100 mg/dl drop in blood glucose) is ideal.

- If there is negative Na trend: (i.e. no increase of corrected Na or it decreases to a lower value with the drop of blood glucose) shift back to normal saline (0.9%).

3. **In case of hyperosmolarity or hypernatremia:** use half normal saline after initial fluids replacement.
4. When blood glucose drops to 250 - 300 mg/dl, introduce glucose in the fluids with the half normal saline (saline 0.45%: glucose 5%) at a ratio of 1:1 . Use Glucose 10% or even 12.5 % in cases with persistent ketoacidosis as in this case the insulin dose should not be reduced (goal not reached yet), therefore a higher concentration of IV glucose should be used to avoid hypoglycemia).

II. Insulin therapy

1. Start insulin after 1-2 hours of deficit fluid therapy (as insulin may aggravate hypovolemia).
2. Prepare by adding 50 U regular insulin to 50 cc 0.9% normal saline, so every 1 ml contains 1 unit of insulin.
3. Rate of insulin infusion 0.05 – 0.1 U/kg/hr.
4. Continue till laboratory resolution of DKA (ph > 7.3, bicarbonate > 15, and BOHB < 1 mmol or closure of the anion gap).
5. The target is to achieve **hourly reduction** of the blood glucose ranging between **36 – 90 mg/dl.**
6. When the blood glucose reaches a range between 250 – 300 mg/dl start infusion of glucose saline as mentioned before; and the dose of insulin may be reduced, but only if acidosis has been resolved.
7. If after initial fluid expansion BG drops more than 90 mg/dl/hr, consider adding glucose to fluids even before reaching BG 300 mg/dl.
8. If it happens that blood glucose reaches less than 100 mg/dl, give a bolus of glucose 10% (2ml/kg).

III. Potassium replacement

1. The rule is to add potassium at a rate 40 mEq/L after the initial fluid replacement.

2. If the patient is hyperkalemic, defer potassium replacement therapy until urine output is documented.
3. If the patient is hypokalemic start potassium with the initial fluid therapy.
4. If urine output is documented and no potassium readings are yet available, give 20 mEq/L till results are available.
5. Change the rate according to the serum potassium level.
6. The maximum rate of potassium is (0.5 mEq/kg/hour).
7. If the serum potassium level is still low despite reaching the maximum rate of potassium infusion, start to reduce the dose of insulin.

IV. Correction of acidosis

1. Acidosis improves with fluids and insulin. Fluids improve tissue perfusion that prevent lactic acidosis and improves kidney function hence allowing more organic acid excretion. Insulin infusion prevents further ketoacid production.
2. Persistent acidosis should raise the possibility of:
   - Hyperchloremic acidosis (hyperchloremia is defined as Na: Cl ratio > 0.79). Chloride induced base deficit= (plasma Na- plasma chloride -32). Hyperchloremic acidosis resolves spontaneously.
   - Persistent hypotension and lactic acidosis
   - Insulin infusion problem or under correction of deficits
   - Consider sepsis
   - Renal failure due to hypoperfusion
3. Check these possibilities before considering adding alkali therapy.
4. Administer bicarbonate ONLY If pH < 7.0 OR HCO_3 <5 mEq/l, Or with life threatening hyperkalemia (K+ level > 6 mEq/l &/or ECG changes: wide QSR and peaked T waves).
5. Dose : 1- 2 mEq/kg over 2 hours
6. Hazards of alkali therapy include:
   - Hypernatremia
   - Hypokalmia
   - Increased anaerobic glycolysis
   - Impaired tissue oxygen delivery
   - Paradoxical fall in CSF pH

V. Monitoring

Clinical monitoring

1. A special flow chart is available for hour by hour clinical and laboratory monitoring.
2. Hourly: vital signs – Glasgow coma scale – warning signs of brain edema – fluid input and fluid output – degree of dehydration – pattern of breathing.

Laboratory monitoring

1. Hourly: capillary blood glucose (better to confirm it laboratory from a venous sample with shock and with blood glucose 600mg/dl as the bed side test is poor in these conditions).
2. Every 2 hours: serum electrolytes (Na – K – CL – Ph), Venous BG, and BOHB (if available).
3. Less frequent: blood urea nitrogen and creatinine.
4. Calculations every 2- 4 hours:
   - Anion gap
   - Corrected sodium
   - Effective osmolality

VI. Management of complications

Brain edema

When to suspect brain edema

- Headache
- Inappropriate slowing of heart rate
- Recurrence of vomiting
- Change in neurological status (restlessness, irritability, incontinence)
- Specific neurologic signs (e.g., cranial nerve palsies, abnormal pupillary responses)
- Rising blood pressure

- Decreased oxygen saturation
- Rapidly increasing serum sodium concentration suggesting loss of urinary free water as a manifestation of diabetes insipidus (from interruption of blood flow to the pituitary gland due to cerebral herniation).

Management of cerebral edema

- Start **once you suspect** the condition
- Transfer to the ICU
- Elevate the head of the bed to 30 degrees
- Reduce the rate of fluid administration by one-third
- Give **mannitol 0.5 gm/kg (2.5 ml/kg of 20% solution) IV over 20 minutes**, repeat if there is no initial response in 30 min to 2 h to control the intracranial pressure or give **hypertonic saline (3%) 5-10 ml/kg over 5 to 10 min.**
- Decrease insulin infusion rate if necessary
- Intubation and hyperventilation if necessary to reduce blood pCO_2.

VII. Transition to SC insulin and oral feeding

- **Shift to SC Insulin and oral feeding when**
  1. pH> 7.3
  2. Bicarbonate > 15 mEq/ dl
  3. B OHB normal (ketonuria persists for hours and should not be used as a guide for resolution of DKA).
  4. Clinical improvement of dehydration.
  5. No emesis (try few sips of water before starting feeding)
- Shift to S.C. insulin should be as early as possible to reduce the incidence of hypoglycemia.
- Give rapidly acting bolus insulin 15 –30 minutes before stopping insulin infusion, or give regularly acting bolus insulin 1-2 h before stopping insulin infusion.
- Give basal insulin few hours before stopping insulin infusion.
- If you start feeding before 48 hours, the total fluids intake (oral and intravenous) should not exceed 1.5-2 times the normal maintenance.